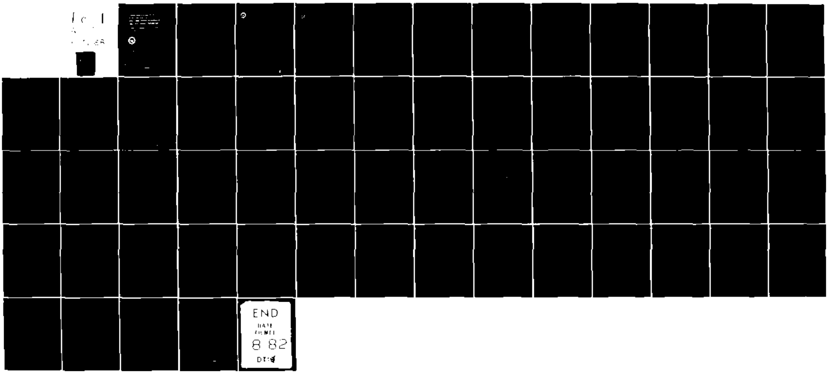
AD-A117 238   OFFICE OF THE UNDER SECRETARY OF DEFENSE RESEARCH AND--ETC   F/G 9/5
OPTIMAL PLANNING AND EXECUTION OF DOD VLSI ACTIVITIES.(U)
FEB 82

UNCLASSIFIED   NL



(13)

DEFENSE SCIENCE BOARD REPORT OF THE TASK FORCE ON

VERY HIGH SPEED INTEGRATED CIRCUITS (VHSIC) PROGRAM

"OPTIMAL PLANNING AND EXECUTION OF DOD VLSI ACTIVITIES"

17 FEBRUARY 1982

OFFICE OF THE UNDER SECRETARY OF DEFENSE
FOR RESEARCH AND ENGINEERING
WASHINGTON, DC

Defense Science Board

REPORT OF THE TASK FORCE ON VERY HIGH SPEED INTEGRATED CIRCUITS (VHSIC) PROGRAM

"Optimal Planning and Execution
of DOD VLSI Activities"

17 February 1982

Office of the Under Secretary of Defense,
Research and Engineering
Washington, D.C.

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

DEFENSE SCIENCE BOARD

23 April 1982

MEMORANDUM FOR SECRETARY OF DEFENSE
CHAIRMAN, JOINT CHIEFS OF STAFF

THROUGH: UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

SUBJECT: Report of the Defense Science Board Task Force on Very High Speed Integrated Circuits (VHSIC) Program--"Optimal Planning and Execution of DoD VLSI Activities"-INFORMATION MEMORANDUM

This report of the Defense Science Board Task Force on the Very High Speed Integrated Circuits program was prepared in response to the 3 September 1981 memorandum from the Under Secretary of Defense for Research and Engineering. The Task Force, under the chairmanship of Dr. William J. Perry, included experienced representatives of the related government, industry and university communities.

I would particularly call to your attention the recommendation that the VHSIC program be used as a model for the organization of other high-thrust areas of the defense technology base where the needs of the Services are very similar and, for cost efficiency, a highly-focused, coherent program is required. Additionally, a procedure has been recommended using technical committee review and predesignation of VHSIC and VLSI-related research and development work units prior to contract award that seems workable and would greatly alleviate the problems of export control in this area. The other recommendations of the Task Force are equally responsive to their tasking assignment including the ones relating to the important area of technology insertion.

In my judgment the VHSIC program is one of the two or three most important technology programs underway in the Department of Defense. This report has received the approval and concurrence of the Defense Science Board and I recommend it for your consideration.

Norman R. Augustine
Chairman

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

DEFENSE SCIENCE
BOARD

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Final Report of the Task Force on Very High Speed Integrated Circuits (VHSIC) Program--"Optimal Planning and Execution of DoD VLSI Activities"

This final report provides the findings and recommendations of the DSB Task Force on VHSIC in response to Dr. DeLauer's memorandum of 3 September 1981. As with any study of this type the findings and recommendations are a somewhat subjective response to a set of complex issues. However, since the Task Force has benefited from many authoritative inputs and represents, through its members, a diversity and depth of experience in governmental, industrial, and academic organizations dealing with the issues being addressed, this report is provided with considerable confidence.

We note that "export controls" have been a topic of considerable concern to the Task Force. A blueprint is provided for application of controls to VHSIC and VLSI activities that will go a long way to preserving the United States lead in this technology. This blueprint should mesh with the broader policy positions now being developed.

Our most important recommendations are succinctly described in the Executive Summary and all of our findings and recommendations are presented separately in the Preface. We urge their adoption for the benefit of VHSIC and the defense technology base. Perhaps, the most fitting summary comment is that each member of the Task Force believes strongly in the importance of the VHSIC Program, is of the opinion that it has progressed very well to this point, and believes that the recommendations provided are essential for the attainment of the ultimate benefits of VHSIC for defense.

William J. Perry

William J. Perry
Chairman
Task Force on VHSIC

REPORT OF DSB TASK FORCE ON VHSIC

Implementation Plan
(VPD = VHSIC Program Director, VSC = VHSIC Steering Committee, VEC = VHSIC Executive Committee)

Recommendation	Comment	Action	Preparer/ Initiator	Approver/ Response
1.0 VHSIC Progress				
1.1 Maintain the goals and schedule of the VHSIC Program through its completion in 1986.	No direct action required.	Monitor	VSC	VEC
1.2 Initiate detailed planning for Phase II consistent with the existing goals.	Completed by 6/82 for FY84 budgeting.	Provide Phase II plan.	VPD	VSC/VEC
1.3 Maintain the high visibility of VHSIC by USDRE. This can be accomplished by having the VHSIC Program Office report directly to the DUSD(R&AT).		Should determine organizational options.	VPD	DUSD(R&AT)
1.4 Provide direct control of funding by VHSIC Program Office.	USDRE program element is preferred.	Identify options/ select preferred funding/control and alternative.	DUSD(R&AT) VPD/ADUSD	USDRE
1.5 Augment staff of VHSIC Program Office.	Immediate action.	Request personnel slots and explore interim detail/loan options.	VPD	USDRE

Recommendation	Comment	Action	Preparer/ Initiator	Approver/ Response
2.0 Funding				
2.1 Support budget in conformity with present budget plan.	Requires $15 M augmentation in FY83 to avoid shortfall.	Support House mark-up, further reprogramming, if required.	DUSD(R&AT)	USDRE
2.2 Determine funding re-requirements for Phase II.	In conjunction with 1.2.	Prepare Phase II budget	VPD	VSC/VEC
2.3 Fund new technology insertion initiative.	See 3.4			
3.0 Technology Insertion				
3.1. Incorporate VHSIC in DSARC and SSARC.	To assure early consideration of VHSIC.	Add specific items to DoD Instr 5000.2.	VPD/MSA	USDRE
3.2 Modify acquisition policies.	Certification, testing, specifications, etc., must be modified for VHSIC.	Revision of acquisition policies	DIR(STDZN & Acquisition Support)	DUSD(AM)
3.3 Designate VHSIC system insertion coordinators.	Will be members of VHSIC Steering Committee	Request designation by Services and user agencies.	VPD/DUSD (R&AT)	Service Asst. Secretaries and agency directors.
3.4 Establish new technology insertion initiative.	Initiate in FY84 budget at $50M/yr.	POM issue; assure that funds are in FY84 President's Budget.	VPD/DUSD (R&AT)	USDRE/ASD Comptroller

Recommendation	Comment	Action	Preparer/ Initiator	Approver/ Response
4.0 Export Controls				
4.1 Apply export controls to VHSIC/VLSI per Table 2 (p.12).	Nine technology elements	Brief contractors and include in future contracts.	VPD	PDUSDRE
4.2 Establish interagency force to modify EAR.	Require participation by other executive departments.	Examine existing task force and committees. Select appropriate organizations.	VPD/IPT	USDRE
4.3 Increase enforcement.	Requires action by enforcement agencies.	Prepare memorandum describing problem and recommending action to enforcement agencies.	IPT	PDUSDRE
4.4 Review VLSI/microelectronic programs and predesignate with respect to applicable controls.	Involved DUSD (R&AT) & DARPA. Blueprint in Table 3 (p.14)	Establish and implement review procedures using AGED in advisory capacity.	VPD/EPS/DUSD (R&AT)	PDUSDRE
5.0 Future Technology				
5.1 Plan for beyond-VHSIC silicon based, program.	Focus on information/control/signal processing electronics, circa 1987-1993.	Prepare plan and budgetary estimates.	VPD/CompSci/AGED	DUSD(R&AT)
5.2 Maintain balanced solid state electronics program.	See Item 5.1			

Recommendation	Comment	Action	Preparer/ Initiator	Approver/ Response
6.0 University Participation				
6.1 Establish Fellowship program.	Coordinate with Implementation Plan of the DSB Summer Study on Tech Base	Coordinate/ Monitor	VPD	DUSD(R&AT)
6.2 Predesignate VLSI research programs with respect to export controls.	See 4.4			
6.3 Apply export controls in conformance with broad DoD policy on university research.	Adapt to policy as it evolves.	No action pending resolution of broader policy issues.		
6.4 Coordinate VLSI/micro-electronics research through AGED and disseminate results.	Includes VHSIC, Service laboratories, independent agencies, research, DARPA, and systems programs.	Assess coordination/ dissemination/ issue directive establishing coordination.	VPD	DUSD(R&AT)

Recommendation	Comment	Action	Preparer/ Initiator	Approver/ Response
7.0 Industry/DoD Relationship				
7.1 Plan beyond-VHSIC silicon based program to maintain industry presence.	See 5.1			
7.2 Participate in industry initiatives.	Defer until industry actions materialize.	Formulate cooperative activities	VPD	DUSD(R&AT)
7.3 Assure (1) dissemination of VHSIC/VLSI technical information and (2) availability of VHSIC chips to non-VHSIC DoD contractors.	Dissemination requires action of all participants.	1. Formulate and issue dissemination policy to all DoD elements participating in VHSIC/VLSI.	VPD/DUSD (R&AT)	PDUSDRE
		2. Strengthen VHSIC chip availability requirements.	VPD	DUSD(R&AT)
8.0 Standardization				
8.1 Establish committee to consider appropriate standards.	Institutionalize existing working committee.	Coordinate appropriate standards with committee.	VPD/DMSSO	VPD
9.0 VHSIC As A Model				
9.1 Extend VHSIC Program model to other high-thrust areas of technology base.	Potential areas identified by DSB Summer Study.	Examine viability of VHSIC model for other technology areas.	DUSD(R&AT)	USDRE

Recommendation	Comment	Action	Preparer/ Initiator	Approver/ Response
10.0 DoD Microelectronics Laboratories				
10.1 Avoid upgrading existing DoD labs to VHSIC technology.	Control funding.	Prepare policy memorandum to Service secretaries.	VPD	DUSD(R&AT)/USDRE
10.2 Establish objective of DOD controlled VHSIC facility.	Internal DUSD (R&AT)/OUSDRE planning activity.	Definition of VLSI facility objectives.	VPD	DUSD(R&AT)
10.3 Examine possibilities for combining with other relevant technologies.	Internal DUSD (R&AT) planning activity.	Definition of broad multi-technology coordination/ factility objectives.	VPD	DUSD(R&AT)
10.4 Appoint Planning Committee for DoD laboratory.	External and internal members.	Detailed facility plan.	VPD/CompSci) DSB	
10.5 Implement.	Requires DoD action.	Provide line items in budget for implementation and operation when appropriate.	DUSD(R&AT)	USDRE

CONTENTS

EXECUTIVE SUMMARY

1. Significance of the VHSIC Program

VLSI technology has brought us to the dawn of a new era. It can provide more than a tenfold improvement in the cost effectiveness of our most important military systems. The development of these "high leverage" systems is the key to our strategy of off-setting the superior numbers of Soviet equipment with the superior performance of our own equipment.

The VLSI revolution is already underway in industry, but it is not vectored to the applications of greatest important to defense. DoD's VHSIC Program is focused on those applications, and is intended to accelerate by three or more years the date by which VLSI will be incorporated in major military systems. It will also have the effect of increasing the near term defense application of advanced LSI technology.

Therefore, we regard VHSIC as the highest priority technology program in the Defense Department and believe that it should receive extraordinary management attention to insure its success. We also believe that VLSI technology is of enormous significance to the competitive posture of U.S. industry and, indeed, to the vitality of our national economy. Therefore, while the enhancement of commercial competitiveness is not one of the goals of VHSIC, it is an important byproduct and should be encouraged.

2. VHSIC Program Objectives

We believe that the VHSIC technical goals are well conceived and that the program has a good probability of achieving them. The selection of 1.25 microns as a "waystation" has proven to be a challenging goal, yet contractors already are showing good results at these geometries. There is good reason to believe that most of the contractors will have brassboards operating at the speed/density requiremens on schedule. The mix of technologies (Bipolar, CMOS, etc.) is an appropriate hedge against the technical uncertainties facing us as we move to 0.5 microns. The program has bet heavily on silicon as the dominant material for VHSIC; we agree with that judgement.

The program has a large number of competitive contractors (six primes plus a number of major subs). While this does not include all of the technical leaders in the semiconductor industry, it does include an impressive mix of leaders whose performance to date generally has been excellent. Most importantly, the program was structured to include a blending of systems contractors with semiconductor manufacturers.

The Program Office is appropriately focused and has done a fine job of bringing the program to its present state. It should be strengthened for the difficult task ahead by giving it direct fiscal control over the program. Conceptually, it could be furthered strengthened by raising its

reporting level, but we do not believe this is required as long as the program continues to command the personal attention of the USDRE and his principal deputies.

The VHSIC budgetary plan should be adequate to achieve the technical objectives of Phases I and III. However, the President's budget for FY83 is $15 M short of the budgetary plan. The definition of Phase II (submicron) is still inadequate and should be resolved. When that is done, it will probably entail additional outyear funding.

The Task Force foresees a continuing necessity for a VHSIC-like program focused on silicon structures beyond the present term of the VHSIC Program; by the end of the century, new active device technologies (such as gallium arsenide) will play an increasingly important role in VLSI, but will not supplant silicon.

3. Technology Insertion

The greatest "risk" in the VHSIC Program, in our judgement, is not that we will fail to achieve the technical objectives, but that we will make a sluggish or incomplete implementation of the technology. Since the primary purpose of the program is to accelerate the implementation of VHSIC technology, such a failure would be serious indeed. To minimize that risk, we recommend a vigorous, well-defined, well-publicized technology insertion effort. It is time to begin planning for this effort. It will require additional funding (perhaps as much as $50 M/yr. beginning in FY84); high level (USDRE) missionary work with the Services, and procedural changes with the acquisition system, for which some suggestions are outlined in our report. Key to successful technology insertion is the incorporation of service systems organizations, into the VHSIC Committee management structures, just as the inclusion system contractors was necessary during the development phase.

We believe that industry is the proper vehicle for "inserting" VLSI technology into DoD systems. Therefore, it is important to facilitate chip availability and design services to non-VHSIC DoD contractors. Additionally, we do not support a proliferation of expensive VLSI facilities in the Services. Instead, we recommend that in-house capability in VLSI fabrication be focused in two government laboratories, one of which would be able to accommodate special security requirements.

4. Technology Transfer

Our lead in VLSI technology is of critical importance to our national security; therefore, we should be willing to take special efforts to protect that lead. But we must recognize that there is no risk-free course of action. If we put no controls on the technology, we risk unnecessary leakage. If we treat all VLSI technology as classified, we hamstring our own efficiency in advancing the technology. Superimposing government

security classification on top of industry's existing systems for protecting proprietary information will entail considerable cost with questionable added value. Imposing security classification on university research will entail the loss of some of our most valued research capabilities.

We need a system which protects the data of most significance to national security without "shooting ourselves in the foot" in the process. We propose that the various classifications and export controls be applied to appropriate elements of the VHSIC technology. Further, that existing technical data export regulations urgently need revisions, to protect the design and process technology which is where the U.S. has its most significant lead, while allowing research to continue the maximum exchange of information, which is necessary for a vital and creative research program. Prior export control categorization of contracts by the Government Project Officer with assistance from a technology advisory group is essential. Those contracts that are likely to develop new "recipes" - either hardware or software - that improve design and fabrication processes would be subject to revised controls. Those projects that are not likely to involve the formulation of "recipes" would not be subject to prior controls. Such a system is not without risk, but we believe that cutting off some of our most talented researchers from VHSIC has even greater risks. We do not know all of the reasons by the U.S. still has a commanding lead over the Soviet Union in innovative technology, but certainly one of the reasons is the free flow of informatino in U.S. research in contrast with the highly compartmented system in the Soviet Union. While we should take reasonable measures to protect our lead, we should not eliminate one of the reasons for that lead.

5. Conclusion

In sum, we are well launched on a technology program of great significance to our national security. We should maintain both the scope and the direction of that effort. It will take a special effort to effect the timely insertion of VLSI technology into our military systems, but that is precisely where the payoff is, so the special effort must be made. We should be prepared to tighten the security measures on VLSI's design and process technology, but should be willing to take some of the risks inherent in free communication among VLSI researchers.

FINDINGS AND RECOMMENDATIONS

The Task Force on VHSIC has thoroughly reviewed the DoD VHSIC Program and has addressed each of the issues contained in its charge as well as an additional issue, that of the role of DoD laboratories with VHSIC capabilities. This review has been aided greatly by presentations from DoD, university, and industry leaders identified in the Appendix. It has been found that VHSIC is an exemplary DoD technology program responding to critical needs and progressing well. The findings and recommendations presented here and amplified in the text are concerned primarily with the continuation of this success to where VHSIC and beyond-VHSIC technologies are fully developed and become operational in defense systems.

VHSIC PROGRESS

Question: Is the VHSIC Program satisfactorily proceeding with respect to technical, managerial, and political factors in such a way so as to meet the intended goals to develop environmentally and fault-tolerant digital electronics with high signal-processing throughput and to introduce this technology into the operational inventory at the earliest possible time? If not, what changes are recommended?

Finding: In the context of its political, management, and technical environment, the VHSIC Program has exhibited exemplary progress. Management attention is required in order to maintain the momentum of this most important of all DoD technology programs. The technical goals are reasonable, Phase I is progressing well, and there is no need to alter the plans and schedule as they now exist.

Recommendations

1. Maintain the goals and schedule of the VHSIC program through its completion in 1986.

2. The Project Office should initiate detailed planning for Phase II consistent with the existing goals.

3. Maintain the high visibility of VHSIC by the USDRE. This can be accomplished by having the VHSIC Program Office report directly to the ASD (Research and Technology).

4. Provide direct control of funding preferably by means of a USDRE program element.

5. Strengthen the Office by the augmentation of the staff based on the recommendation of the Program Director in order to provide adequate management of the program.

FUNDING

Question: Is the funding adequate to meet the goals in the time frame identified in the program plan? If not, how much should it be augmented and how?

Finding: For the VHSIC Program as now defined and underway, the funding plan as revised in 1981 is adequate for Phases I and III. Phase II needs in the budget plan are the original estimates and have not yet been modified to take into account the knowledge gained in the program. The present funding plan is not now fully budgeted. It is assumed that $25 M will be made available through POM procedures in FY83. An additional augmentation of $15 M is required to the President's budget for FY83. In addition to the program funding, significant additional funding will be required to incentivize timely and effective technology insertion.

Recommendations

1. Support the budget in conformity with the current funding plan by providing $25 M through POM procedures and an additional $15 M augmentation in FY83. Should program shortfalls occur, accommodate these by reducing the number of contracts rather than by dilution of the efforts of all contractors.

2. Determine funding requirements of Phase II.

3. Fund a new initiative for insertion of VHSIC technology. (See recommendations under technology insertion.)

TECHNOLOGY INSERTION

Question: What policies, directives, incentives and funding should be provided to cause the adoption and use of the VHSIC technology in the next generation of weapon systems?

Finding: Technology insertion is in its formative stages and has received adequate emphasis to date. The introduction of VHSIC into operational systems cannot be forced through directives but must be encouraged through other means. In order to obtain increased momentum as the development effort matures, it will be necessary to provide policy guidance to DoD system developers requiring early consideration of VHSIC technology and hardware and to provide additional funding for incentivizing insertion efforts and for demonstrations. It will also be necessary to examine and possibly modify certification and acceptance testing for VHSIC hardware.

Recommendations

1. Direct the early planning for VHSIC technology demonstration and insertion through incorporation of VHSIC requirements in the DSARC and the Service's system acquisition review procedures (SSARC) for the signal processing portion of systems entering development in or after FY83 and production after FY85. Recognizing that system review procedures are now being modified, the intent of this recommendation is to require VHSIC planning in appropriate system R&D programs exceeding $10 M and system production programs exceeding $100 M.

2. Modify acquisition policies to be consistent with VHSIC technology and to facilitate technology insertion. Certification, testing, and other standards requirements must be reevaluated for their value and applicability.

3. Designate a coordinator from the systems community of each Service and from DoD independent user agencies to be responsible for timely and effective VHSIC insertion into systems and to serve on the VHSIC Steering Committee.

4. Establish a new initiative consisting of a 6.3A budgetary augmentation ($\sim$ $50 M/yr) under the direct control of the VHSIC Program Office (USDRE program element) directed to the early application of VHSIC technology in selected high priority military systems. The VHSIC Program Office would allocate the funds to specific demonstration and insertion efforts based on proposals originating in the system community. This activity should begin in FY84.

EXPORT CONTROLS AND VHSIC

Question: What export controls should be imposed on this technology to prevent the loss of the lead we are gaining on potential adversaries by funding this program?

Finding: Export controls are necessary for critical elements of the VHSIC technology and for keystone equipment and materials used in its practice. The dual-use nature of some elements of this technology complicates the problem of its control. Existing controls for defense articles (National Security classification and the International Traffic in Arms Regulations) are adequate and appropriate for strictly defense-related items, however, existing controls for dual-use elements are currently inadequate both in coverage (in the case of technical data) and enforcement. New controls and increased enforcement that are needed before dual-use VHSIC technology can be removed from the ITAR should be given immediate attention.

VHSIC programs carried out within university academic departments should be pre-reviewed to determine if critical technology might result. Controls should be applied as appropriate.

Although VHSIC is the most important high-thrust defense technology and is thus a prime candidate for export controls, the Task Force believes that, in general, VHSIC should follow the lead being established by the broader discussions now taking place.

Recommendations

1. Apply the various export controls to the VHSIC Program and other DoD VLSI activities as shown in Table A. Brief all VHSIC contractors on these controls as soon as possible.

2. Establish a task force on technology controls to recommend changes in the EAR so as to control dissemination of recipe technology, software, and remote design services. Members of this committee should include representatives from the Departments of Defense, State, and Commerce, as well as the intelligence community and the merchant-market semiconductor industry. The Task Force should report to a sufficiently high governmental level (e.g., the President's Science Advisor) to insure effective implementation of Task Force recommendations.

3. Increase enforcement of existing critical technology transfer and equipment regulations to deny potential adversaries access to already embargoed critical items.

4. Review VHSIC and other DoD VLSI/microelectronics contractor programs, with the advice of the Advisory Group on Electron Devices, to identify and implement appropriate controls as shown in Table B. Predesignate projects with respect to applicability of controls before contracts are awarded.

TABLE A. RECOMMENDED VHSIC TECHNOLOGY CONTROLS

	TECHNOLOGY ELEMENT	APPLICABLE CONTROL
1.	Military systems brassboards	DoD Classification/Arms Export Control Act (ITAR)
2.	Military systems software	DoD Classification/Arms Export Control Act (ITAR)
3.	Integrated circuits and intermediate products (masks, rejects) designed for use only in military systems	DoD Classification/Arms Export Control Act (ITAR)
4.	Integrated circuits and intermediate products (masks, rejects) having substantial application outside of military systems and technology that may be inferred from analysis of finished IC products	Export Administration Act Per Commodity Control List (EAR)
5.	Recipe technology that may not be inferred from analysis of finished IC products	Interim: Arms Export Control Act (ITAR) Final: Upgraded Export Administration Act
6.	Keystone fabrication equipment used in VHSIC technology	Export Administration Act Per Commodity Control List (EAR)
7.	Design and test generation software	Interim: Arms Export Control Act (ITAR) Final: Upgraded Export Administration Act
8.	Remote design services	Interim: Arms Export Control Act (ITAR) Final: Upgraded Export Administration Act
9.	Basic (university) research results	No control

TABLE B. VHSIC RESEARCH PROGRAM CATEGORIES*

	CATEGORY	CONTROL	MOST LIKELY CONTRACTORS
1.	Research that will *not* result in EAR** controllable technology	No restrictions	Universities
2.	Research that might result in EAR** controllable technology	No restrictions during research phase. Contractor must agree to review of publications by contracting officer's technical designee.	Universities and other research contractors
3.	Research and development that will result in EAR** controllable technology	Temporary ITAR control, final control under EAR.**	Merchant-market semiconductor, manufacturing equipment, and software companies
4.	Research and development that will result in single-use defense article technology	National security classification and ITAR control as appropriate.	Defense systems companies

*Category to be determined by contracting officer with the advice of AGED.

**EAR as used here refers to modified EAR technology controls per Recommendation 2.

FUTURE TECHNOLOGY EFFORT

Question: What solid state electronic program lies beyond VHSIC? What should be emphasized in current research under the DARPA Program for eventual transition to the VHSIC Program?

Findings: Since the mainstream of electronic advances will be based on silicon devices for the next several decades, a solid state electronics program to follow VHSIC will necessarily be focused on the next generation of those capabilities that are now the focus of VHSIC. Solid state devices based on other materials will continue to be important for a variety of special applications. Increased coordination between the several DoD agencies engaged in VLSI R&D is highly desirable and improved dissemination of technical results from those several programs should be required.

Recommendations

1. Recognize in forward planning and budgeting that either VHSIC or its equivalent in DoD development of solid state electronic systems will extend beyond the presently planned VHSIC Program termination in 1986. Emphasis should be placed on insertion of VHSIC-II technology and on further extension of VLSI technology.

2. Maintain a balanced solid state electronics program in which silicon devices are accepted as the most important components of military electronic systems for the foreseeable future but in which specialized device technologies based on other materials are recognized as making essential contributions to electronic technology.

UNIVERSITY PARTICIPATION

Question: What is the proper relationship between the university community and the VHSIC Program? Should the DoD research (6.1) program be directed to support VHSIC technology?

Findings: Universities have and will continue to make important contributions to the DoD VLSI/VHSIC activities by (1) providing important creative and innovative inputs to generic materials, processing, device, and systems science and technology, and (2) by training the personnel that are critical to the continued development of military technology in this field.

DoD university related VLSI research activities include areas of critical importance to VHSIC. The coordination of these activities and the dissemination of research results from them required added emphasis.

Recommendations

1. Adopt the recommendation of the DSB Summer Study and implement an expanded DoD university fellowship program to produce more qualified technical personnel.

2. Predesignate DoD VLSI research programs with respect to application of export controls, subject to review at any time by OUSDRE. (See Recommendations on Export Controls.)

3. Follow DoD policy with respect to applicability of controls to university VLSI research.

4. Direct DoD research organizations to coordinate all VLSI/microelectronics research through AGED and to disseminate results to the VHSIC community through summary reports on other effective means, but to avoid introduction of delays in the execution of programs.

INDUSTRY/DoD RELATIONSHIP

Question: Will VHSIC effectively help DoD maintain a major presence in this dynamic industry with less than 7 percent of the market? What else can be done?

Finding: VHSIC, because it is large enough and its goals complement those of the industry, has been highly successful in reestablishing a DoD presence in the semiconductor industry and in obtaining leverage for its investment. In the future, the nature of this presence will depend on where and how DoD buys VLSI. The dissemination of VHSIC results and the availability of VHSIC chips to all DoD contractors remain a vital concern to non-VHSIC DoD contractors.

Recommendations

1. Continue DoD presence in the semiconductor industry after the completion of the VHSIC Program by means of a VHSIC-like program that addresses the next generation of VLSI devices for military systems in order to assure a source for future DoD VLSI to meet the bulk of DoD VLSI needs with devices from the commercial mainstream.

2. Participate in industry initiatives directed toward meeting manpower and research needs of the U.S. microelectronics industry (such as the proposed Semiconductor Research Cooperative).

3. Provide effective mechanisms that assure dissemination of technical information developed in VHSIC and other DoD VLSI programs to all DoD contractors and for assuring the early and continuous availability of VHSIC chips to non-VHSIC DoD contractors.

STANDARDIZATION

Question: What standardization measures are recommended to assist the economical utilization of this technology without stifling innovation?

Finding: Standardization should be limited, at this time, to the assurance of interoperability and should not be applied to chip types or technologies. At an appropriate time, interactions with users will determine form, fit, and function.

Recommendations

1. Establish a committee consisting of representatives of government and industry standardization officials to recommend appropriate standards and to consider means for their implementation.

VHSIC AS A MODEL

Question: Should VHSIC be a model for other vertically integrated technology-based programs?

Finding: The organizational structure of the VHSIC Program is an appropriate model for the vertical integration of other DoD technology-based programs.

Recommendations

1. Extend the VHSIC model for vertically integrated technology base programs to other areas of the technology base. The recommendation of the 1981 DSB Technology Base Summer Study and the specific candidates recommended in that study are supported by this Task Force. These candidates consist of software, machine intelligence, composite materials, high power microwaves, and computer aided training.

DoD MICROELECTRONICS LABORATORIES

Question: What should be the role of DoD laboratories in the VHSIC/VLSI era?

Finding: It is not practical for DoD to support a proliferation of expensive service laboratories with VHSIC/VLSI capabilities extending to pilot production.

Recommendations

1. Do not provide funds for upgrading existing DoD laboratories for VHSIC level device technology. This should not inhibit design and application R&D activities which should be encouraged.

2. Establish an objective of creating one or two DoD-controlled VHSIC/VLSI R&D facilities extending from research to pilot production.

3. Examine in detail the possible combination of the proposed DoD VHSIC facility with the other relevant generic technologies and techniques required to form a DoD Electronics and Information Systems Laboratory.

4. Appoint a special planning committee to identify and evaluate the options for implementing, establish a schedule, and define a charter for this laboratory.

5. Implement the plan.

1.0 VHSIC PROGRESS

Question: Is the VHSIC Program satisfactorily proceeding with respect to technical, managerial, and political factors in such a way so as to meet the intended goals to develop environmentally and fault-tolerant digital electronics with high signal-processing throughput and to introduce this technology into the operational inventory at the earliest possible time? If not, what changes are recommended?

Finding: In the context of its political, management, and technical environment, the VHSIC Program has exhibited exemplary progress. Management attention is required in order to maintain the momentum of this most important of all DoD technology programs. The technical goals are reasonable, Phase I is progressing well, and there is no need to alter the plans and schedule as they now exist.

Background: From its inception in 1977 through the present, the VHSIC Program has been defined, structured, and implemented at a pace that is outstanding both in view of the innovations required in DoD program management and in light of the political and industry environment. The melding of Tri-Service technical and procurement activities to obtain an integrated program has been successfully accomplished, the industry has accepted VHSIC as a highly important DoD technology thrust, and the requirements of the Congress have been met.

It is noteworthy that 10 of the 17 important technologies identified by the DSB Summer Study on the Technology Base are directly associated with the VHSIC technology or its products, and that VHSIC was identified as the program with the greatest potential impact on defense capabilities.

VHSIC research and development is now being carried out under 6 Phase I and approximately 59 Phase III contracts. VHSIC-I contracts are 3 years in duration and range from about \$20 M to \$35 M in total funding. Their coverage includes all of the candidate device technologies, a variety of design approaches, 28 complex VHSIC chips, and 6 important brassboards for demonstration of system applications. The 59 VHSIC-III contracts represent a total investment of approximately \$36 M with the largest single contract at \$4.5 M. About 31 research organizations are included, of which 6 are universities. Major investment areas are device and system architectures, lithography, design automation, processing technology, reliability, testing, and characterization.

Specifications for VHSIC chip sets include environmental, fault tolerance, and performance requirements that are challenging yet realizable. Each Phase I contractor has accepted these specifications and has indicated that they will be met or exceeded. The functional-throughput-rate goal for Phase I, 5×10^{11} gate Hz/cm^2, must be coupled with a minimum chip size or complexity level to completely express the performance goal. The radiation hardness specification for VHSIC does not meet the design goals for space systems. Fault tolerance and built-in-test goals for VHSIC are given, but the approaches described by the Phase I contractors do not

respond well to these goals at present. Since Phase I awards were made less than one year ago, any conclusions relative to the ultimate results would be premature.

The VHSIC Program has been managed by a director from the Electronics and Physical Sciences Office of DUSD(RAT) working with a Tri-Service steering committee. Program management was recently augmented by the addition of a temporary Deputy Director for Systems and Technology Insertion.

Discussion: The VHSIC Program has been criticized for not responding adequately to the competitive problems of the U.S. semiconductor industry vis-a-vis Japan. There are significant problems of the highest national concern regarding this competition and, should the relative competitiveness of the U.S. industry deteriorate, this could have profound effects on the Defense technology base. There are indications that in some important technical areas, notably semiconductor memories, the United States is now behind the Japanese industry and that this situation will continue to deteriorate without positive remedial action by the U.S. industry. However, the VHSIC Program was not designed to address the fundamental problems of the industry but rather to meet the urgent requirements of military systems. It must be evaluated with respect to its reponse to these DoD needs, not industry problems, although DoD should participate in the formulation of and support a broader national response to international competition in high technology industries. The Task Force has noted with enthusiasm the initiatives of the American Electronics Association and the Semiconductor Industries Association in addressing these issues.

An early perception by both Congressional and DoD pundits of a DoD VLSI program was that a fragmented approach would be ineffective. It was essential that the available resources be strongly focused via an integrated management structure. The mechanism of a Tri-Service effort with firm control by a program office operating under the Undersecretary of Defense (Research and Engineering) was selected. This runs counter to past practices of apportioning the funding among the three services where three loosely coordinated, often redundant efforts, are established. In the VHSIC Program, the funding required to cover the competitive technologies and to obtain broad participation was known to be substantial. The investment required in industry to establish a state-of-the-art wafer processing capability had escalated from $1 M in the early 1970's to over $50 M at the end of the decade. This indicates that even with considerable leverage of industrial funding, the VHSIC funds should be tightly focused on the defined objectives. This approach has been successful in view of the fact that effective management linkages from the Program Office to the in-place R&D organizations of the military services have been created and are responsive to the decisions of the Program Steering Committee on which the Services are represented by their Program Directors. The Army, Navy, and Air Force have awarded and managed all contracts. As the protocols mature, this management structure should mature and avoid the sometimes conflicting signals received from the in-line R&D organizations. Because VHSIC Program management is an unfamiliar matrix imposed on the line management of the three Services, it will continue to require firm support and strengthening

of DoD management in order to continue its success and to achieve the early technology insertion goals set for it.

The Task Force believes that VHSIC success to date is a result of astute management rather than of the management structure. In order to maintain program momentum, the VHSIC Program Office should be strengthened both in terms of personnel, of its reporting level within the research and technology organization of DoD, and of its control of program funding. An elevation of the reporting level is not important so long as the VHSIC Program continues to command the personal attentin of the USDRE and his principal deputies. While specific recommendations are made on each of these matters, the Task Force recognizes and accepts the fact that the same result can be obtained by alternate means.

With respect to the technical aspects of the VHSIC Program, the rapid development of the $168 M Phase I and $36 M Phase III efforts have inevitably resulted in insufficient emphasis of some goals and a necessity to make adjustments in the program as it proceeds. For example, the functional-throughput-rate goals are met or exceeded in all Phase I proposals, but the approaches for achieving availability, reliability and built-in-test, radiation tolerance, and technology insertion goals are less definitive and will require continuing attention. Since Phase III contracts were awarded in parallel with the Phase 0 efforts, the investment strategy was not coordinated with the Phase I emphasis and requires reexamination. For example, the lithography commitment in Phase III, >$12 M, is excessive in view of subsequent Phase I efforts, particularly the Hughes/Perkin-Elmer $8 M direct-write E-beam development effort. The VHSIC Steering Committee is currently undertaking a restructuring of Phase III. It is necessary that the goals, accomplishments, and investment strategy of the entire program be reviewed on a continuing basis and modifications be implemented as indicated.

The Phase II submicron effort is of critical importance to the overall VHSIC program because it will provide the needed advancement of the technology beyond the present state-of-the-art. Its goals and schedule as originally stated remain valid. It is important that the research into submicrometer technology being conducted in Phase Ib be reviewed and that definitive planning for the Phase II pilot production of submicrometer chips be initiated.

The recommendations given below are intended to maintain the considerable momentum attained by the program and to assure its success.

Recommendations

1. Maintain the goals and schedule of the VHSIC program through its completion in 1986.

2. The Project Office should initiate detailed planning for Phase II consistent with the existing goals.

3. Maintain the high visibility of VHSIC by the USDRE. This can be accomplished by having the VHSIC Program Office report directly to the ASD (Research and Technology).

4 Provide direct control of funding preferably by means of a USDRE program element.

5. Strengthen the Office by the augmentation of the staff based on the recommendation of the Program Director in order to provide adequate management of the program.

2.0 FUNDING

Question: Is the funding adequate to meet the goals in the time frame identified in the program plan? If not, how much should it be augmented and how?

Finding: For the VHSIC Program as now defined and underway, the funding plan as revised in 1981 is adequate for Phases I and III. Phase II needs in the budget plan are the original estimates and have not yet been modified to take into account the knowledge gained in the program. The present funding plan is not now fully budgeted. It is assumed that \$25 M will be made available through POM procedures in FY83. An additional augmentation of \$15 M is required to the President's budget for FY33. In addition to the program funding, significant additional funding will be required to incentivise timely and effective technology insertion.

Background: The original funding estimates for the VHSIC Program totaled \$225 M. Upon receipt of Phase I proposals in late 1980 and consideration of the many options, an increase to \$324 M was recommended in order to provide adequate coverage of the competitive technologies and a representative minimum set of high priority brassboards. The major change was in funding for Phase I which increased from \$82 M to \$168 M. This recommendation has been endorsed and the required augmentations for FY81 and FY82 were budgeted. The augmentation for FY83 is not fully budgeted.

Phase II of VHSIC, which requires system demonstrations of 1.25 micrometer integrated circuits and the pilot production of submicrometer chips, is allocated \$75.6 M in the funding plan. The structure and goal set for this phase will very likely be modified by the results obtained in Phases I and III. Thus, the funding for Phase II must be considered to be a preliminary budgetary estimate.

In addition to VHSIC, significant VLSI funding is being provided by DARPA and the military services.

Discussion: The funding plan for Phases I and III of the VHSIC Program currently appears to be at the proper level for the program although this program is not now fully budgeted for FY83. The Phase III effort is oriented primarily to providing technology support for Phases I and II and not to providing the necessary research to undergird all DoD VLSI interests. An additional budgetary initiative is required to demonstrate the VHSIC technology in brassboards beyond the six funded in Phase I. A number of additional unfunded but very important brassboards have been proposed and more will be identified as the VHSIC technology advances. It is highly desirable that VHSIC technology be applied as rapidly as possible in all types of systems in order to realize the full value of the program.

The funding requirements of Phase II are estimates made at the beginning of the VHSIC Program. These estimates should be updated and the funding requirements for FY84 and subsequent years determined.

Recommendations

1. Support the budget in conformity with the current funding plan by providing $25 M through POM procedures and an additional $15 M augmentation in FY83. Should program shortfalls occur, accommodate these by reducing the number of contracts rather than by dilution of the efforts of all contractors.

2. Determine funding requirements of Phase II.

3. Fund a new initiative for insertion of VHSIC technology. (See recommendations under technology insertion.)

3.0 TECHNOLOGY INSERTION

Question: What policies, directives, incentives and funding should be provided to cause the adoption and use of the VHSIC technology in the next generation of weapon systems?

Finding: Technology insertion is in its formative stages and has received adequate emphasis to date. The introduction of VHSIC into operational systems cannot be forced through directives but must be encouraged through other means. In order to obtain increased momentum as the development effort matures, it will be necessary to provide policy guidance to DoD system developers requiring early consideration of VHSIC technology and hardware and to provide additional funding for incentivizing insertion efforts and for demonstrations. It will also be necessary to examine and possibly modify certification and acceptance testing for VHSIC hardware.

Background: From the earliest discussions of VHSIC, rapid technology insertion has been recognized as a program imperative. Technology insertion has been designed into the Phase I effort, has been emphasized in the information dissemination, and is a major management concern.

The Phase I effort is vertically integrated to provide continuity from chip design through system demonstration. Chip architectures are required to be responsive to specific system requirements, and the selected brassboards are current priority needs of DoD users that will have a high probability of early application. Efforts are underway to broaden the scope of system demonstrations by integrating the VHSIC Program with ongoing system development efforts so as to reduce the technology transition time.

One of the DoD needs for which VHSIC is designed is that of rapid technology implementation. This has been continually reinforced in dissemination of information to the technical community and in program reviews. In each instance, the approaches to chip design and processing have been associated with analyses of the application scenarios and their requirements. The emphasis on DAST as a necessary program element for promoting technology insertion is one example.

Management concern with technology insertion has extended to designating a Deputy Director for Systems and Technology Insertion as the second position in the Program Office, the issuance of a specification handbook directed to the needs of DoD contractors not now directly participating in the program, and continuing discussions with DoD user agencies and groups. These efforts are being supplemented by vigorous technology insertion efforts by some Phase I contractors.

Discussion: The importance of rapid technology insertion to provide visible and useful demonstrations of the VHSIC chip technology cannot be overemphasized. The payoff of the large investment and the viability of the management approach must be apparent to the DoD community during the life of the program; otherwise, the impact will be diluted. Moreover, U.S. military systems must be provided with the technology rapidly in order that key defense systems can become operational when needed to offset the continued growth of adversary forces and to maintain a credible response capability.

The motivations for technology insertion are:

- Higher performance in an existing function at the same cost.
- Equivalent performance at a lower cost.
- Performance of a new function.
- Higher reliability.
- Reduced size and weight.
- Lower power.
- Ease of maintenance.

Emphasis among those benefits varies among different systems depending on their status and performance. Certain planned systems require VHSIC performance to achieve operational objectives. It should be noted that technology insertion of VHSIC parts to replace present digital components will greatly increase system capability, while replacement of analog or electromechanical components will probably have more impact on reliability and life cycle costs. The weapon system acquisition process must accommodate realistic technology insertion plans instead of their becoming as an afterthought.

There is a danger of early overkill. By pushing hard for VHSIC applications before many chip designs are completed, before successful chips have been fabricated and reliability assured, and certainly long before the first chips will become available, the program is accepting a high-risk high-payoff strategy. The risk is that promises will be made but not fulfilled, that systems will be committed to VHSIC chips that cannot be delivered on schedule, and that the political and technical communities will react adversely. The payoff is early technology insertion, perhaps fully justifying the risk because of its value.

DoD Directive 5000.1 and DoD Instruction 5000.2 provide policy and procedures for the management and review of major defense system acquisitions. Both of these documents are currently being updated to reflect the SEC DEF/DEP SEC DEF decisions on improving the acquisition process. DoD Directive 5000.1 states under objectives - Ensure that an effective acquisition strategy is developed and tailored for each system acquisition program.

The appropriate time for consideration of VHSIC Technology Insertion would be at the time that a Justification for a Major System New Start (JMSNS) is submitted with the Program Objectives Memorandum (POM). One way that this could be accomplished would be for R&AT to obtain a listing of major new starts identified in the POM from DUSD(AM) after the POM is submitted. The designation in the new start justification should give some clue as to plans for VHSIC Technology Insertion. If it does not and if R&AT considers the proposed system to be an appropriate candidate, an issue paper could be generated on the major system new start in question. Under the new procedures the issues which are raised during the POM review have to be resolved and SEC DEF decisions have to be documented in a Program Development Memorandum (PDM). Major systems new starts, under the new procedures, would be designated in a PDM and if changes (such as VHSIC Technology Insertion) are directed by SEC DEF, these would also be set forth in the PDM.

At the current time the Defense Systems Acquisition Review Council (DSARC) triggers at $200 M RDT&E or $1 billion in production. The individual services SARC trigger at RDT&E at $50 M and production in excess of $200 M but at least the RDT&E is expected to double shortly. It is felt that VHSIC Insertion would benefit with a lower trigger level for appropriate programs.

In connection with Technology Insertion, the aspect of interoperability cannot be overemphasized. In most cases, enough of the parts that "play together" are required for systems effectiveness. VHSIC parts will replace assemblies of earlier components, which have a body of operating and reliability data available. Interface modeling of VHSIC and non-VHSIC parts is necessary if adequate operational and reliability testing is to be properly accomplished.

Technology insertion objectives can be met only if (1) the Service's system communities are brought into the program and (2) technology insertion is funded. To date, participation in the VHSIC Program has been confined to the service electronic technology communities, and significant funding for the insertion of VHSIC technology into systems has not become available.

Recommendations

1. Direct the early planning for VHSIC technology demonstration and insertion through incorporation of VHSIC requirements in the DSARC and the Service's system acquisition review procedures (SSARC) for the signal processing portion of systems entering development in or after FY83 and production after FY85. Recognizing that system review procedures are now being modified, the intent of this recommendation is to require VHSIC planning in appropriate system R&D programs exceeding \$10 M and system production programs exceeding \$100 M.

2. Modify acquisition policies to be consistent with VHSIC technology and to facilitate technology insertion. Certification, testing, and other standards requirements must be reevaluated for their value and applicability.

3. Designate a coordinator from the systems community of each Service and from DoD independent user agencies to be responsible for timely and effective VHSIC insertion into systems and to serve on the VHSIC Steering Committee.

4. Establish a new initiative consisting of a 6.3A budgetary augmentation ($\sim$ \$50 M/yr) under the direct control of the VHSIC Program Office (USDRE program element) directed to the early application of VHSIC technology in selected high priority military systems. The VHSIC Program Office would allocate the funds to specific demonstration and insertion efforts based on proposals originating in the system community. This activity should begin in FY84.

4.0 EXPORT CONTROLS AND VHSIC

Question: What export controls should be imposed on this technology to prevent the loss of the lead we are gaining on potential adversaries by funding this program?

Finding: Export controls are necessary for critical elements of the VHSIC technology and for keystone equipment and materials used in its practice. The dual-use nature of some elements of this technology complicates the problem of its control. Existing controls for defense articles (National Security classification and the International Traffic in Arms Regulations) are adequate and appropriate for strictly defense-related items, however, existing controls for dual-use elements are currently inadequate both in coverage (in the case of technical data) and enforcement. New controls and increased enforcement that are needed before dual-use VHSIC technology can be removed from the ITAR should be given immediate attention.

VHSIC programs carried out within university academic departments should be pre-reviewed to determine if critical technology might result. Controls should be applied as appropriate.

Although VHSIC is the most important high-thrust defense technology and is thus a prime candidate for export controls, the Task Force believes that, in general, VHSIC should follow the lead being established by the broader discussions now taking place.

Background: Export control of technology is a major policy issue affecting VHSIC as well as other critical military technology areas (such as cryptography). The existing export controls applicable to VHSIC are shown in the accompanying Table 1.

National Security classification as an element of the National Disclosure Policy is the most effective control on critical defense technology. Access to classified technology is strictly limited to those having a "need to know." At the same time, however, the cross-fertilization that has characterized the rapid development of the semiconductor technology is severely limited.

Control of VHSIC under the International Traffic in Arms Regulations (ITAR) has been implemented in conformity with guidance provided by the Congressional Authorization Committee "until the state-of-the-art for such technology progresses to the point where national security permits its transfer to other controls for export." ITAR restricts transfer of weapons-related technology and hardware to non-United States destinations as well as to foreign nationals. This last restriction has been a major concern to universities engaged in research under VHSIC. ITAR is generally effective when applied to weapons-related technology and hardware specified on the Munitions List; however, it is not appropriate to the control of "dual-use" technologies which have extensive nonweapons applications. Consideration is now being given to revisions of the ITAR that will improve their administration.

The Export Administration Act of 1979 is meant to apply to sensitive dual-use technology. The Export Administration Regulations (EAR) are centered about the Commodity Control List which specifies licensing guidelines for critical goods and manufacturing equipment. These guidelines are, for the most part, common with the multilateral controls of COCOM and

TABLE 1. EXISTING TECHNOLOGY CONTROLS

CONTROL	RESPONSIBLE AGENCY	NATURE	ITEMS	DESTINATION CONTROL	EFFECTIVENESS	PRIMARY PROBLEM AREAS
National Disclosure Policy (National Security Clearance)	DoD	Access Control	Primary Information	Limited to Need to Know	Excellent	Commercial Semiconductor Manufacturers, Universities. Technology Cross-Fertilization
Arms Export Control Act (ITAR-Munitions List)	DOS/DoD	Disclosure Control	Information and Equipment (Little Control of Mfg. Equipment)	Controls Transfer to All Non-U.S. Destinations and to Foreign Nationals	Good	Universities
Export Administration Act of 1979 (EAR-Commodity Control List)	DOC/DoD	Export License	Primarily Goods and Mfg. Equipment	Primarily to Eastern Bloc	Limited	Information Controls Poor Enforcement Weak Multilateral Control Through COCOM

are intended primarily to prevent critical technology shipments to Eastern Bloc destinations. Technical data controls under Part 379 of the Export Regulations are limited to licensing required for Eastern Bloc destinations. No technical data licenses are required for free world transfers.

Substantial concern has been voiced about the enforcement of the EAR. Cases have come to light over the past several years of shipments both of embargoed manufacturing equipment and technical data to Eastern Bloc destinations. These transfers have been the result of illegal activities within the United States, illegal diversions of equipment and information through third countries and differing interpretations of the multilateral understanding by COCOM partner countries.

Discussion: The VHSIC Program encompasses diverse elements of critical technology. The several different methods of export control each have appropriate applications to the program technology and hardware. The choice of an appropriate method of control must achieve a balance between national security needs and the level of information flow necessary to nurture technical progress.

Clearly, national security classification is necessary to protect against disclosure of critical weapons systems know-how, brassboards, and software. This work has only weapons applications and is carried out within contractor and military facilities well suited to dealing with sensitive technology. The ITAR should be applied to components specifically designed for use only in such systems.

Control of fabrication technology and design software is a more difficult issue. The substantial range of applications of this work to non-defense uses and the commercial nature of many of the semiconductor fabricators makes military classification inappropriate. Control of information flow in an open society is a difficult task.

The definition of "critical technology" has been a problem in determining how to control it. For purposes of VHSIC, this committee considers the critical technology to be the "recipes" that spell out complete fabrication sequences and that detail the keystone manufacturing equipment needed to produce VHSIC-level devices. "Recipe" technology is considered to consist of those elements of the technology which cannot be directly discerned from the analysis of products built using the technology. Recipe technology includes design software and remote design services.

Existing EAR controls for critical technology information are not adequate. Complete restriction of information dissemination is difficult to enforce because of the many informal means of transmission. However, the committee believes that restricting transfer through controls on documentation containing recipe information and restricting foreign nationals from access to recipe information is sufficient to create the atmosphere of sensitivity to the control of critical information while allowing technological cross-fertilization to take place.

The EAR should be enhanced to require export licensing of all documented technology transfers (including design software transfers and remote design services) to all non-U.S. locations. Guidelines for such transfers should be frequently reviewed with respect to foreign availability of comparable technology and the needs of national security so as not to place U.S. semiconductor manufacturers at a disadvantage with respect to foreign competition. In addition, all publications resulting from VHSIC recipe-type activities should be reviewed by the appropriate DoD contracting officials to determine their publishability.

Until appropriate changes are made to the EAR, VHSIC recipe technology should remain under the ITAR; however, the potential dual-use of the technology makes upgrading of the EAR's a very high priority need.

Control of dual-use products built using VHSIC-level technology and control of the fabrication equipment required should remain under the EAR. Enforcement of export licensing requirements must improve, however, if potential adversaries are to be denied current fabrication capability. Responsibility for enforcement of EAR is currently divided between local police, the FBI, the Department of Commerce, and the Customs Service and receives inadequate attention from each. Furthermore, few enforcement officials are capable of recognizing semiconductor products and equipment.

VHSIC and other VLSI/microelectronics proprosals from university academic departments should be reviewed by contracting officers, with the advice of the Advisory Group on Electron Devices, to determine whether recipe-type technology might result. If no recipe technology will be produced, the program should not be subject to export controls. Where recipes might arise from the research, the contractor should agree that resulting publications should be subject to review by the contracting officer to determine publishability. If recipe technology will definitely result, the contractor must agree to appropriate controls before the contract is let. This procedure results in large areas of material, device, phenomena, software, architecture, design, and processing that are free of controls.

Recommendations

1. Apply the various export controls to the VHSIC Program and other DoD VLSI activities as shown in Table 2. Brief all VHSIC contractors on these controls as soon as possible.

2. Establish a task force on technology controls to recommend changes in the EAR so as to control dissemination of recipe technology, software, and remote design services. Members of this committee should include representatives from the Departments of Defense, State, and Commerce, as well as the intelligence community and the merchant-market semiconductor industry. The Task Force should report to a sufficiently high governmental level (e.g., the President's Science Advisor) to insure effective implementation of Task Force recommendations.

TABLE 2. RECOMMENDED VHSIC TECHNOLOGY CONTROLS

	TECHNOLOGY ELEMENT	APPLICABLE CONTROL
1.	Military systems brassboards	DoD Classification/Arms Export Control Act (ITAR)
2.	Military systems software	DoD Classification/Arms Export Control Act (ITAR)
3.	Integrated circuits and intermediate products (masks, rejects) designed for use only in military systems	DoD Classification/Arms Export Control Act (ITAR)
4.	Integrated circuits and intermediate products (masks, rejects) having substantial application outside of military systems and technology that may be inferred from analysis of finished IC products	Export Administration Act Per Commodity Control List (EAR)
5.	Recipe technology that may <u>not</u> be inferred from analysis of finished IC products	Interim: Arms Export Control Act (ITAR) Final: Upgraded Export Administration Act
6.	Keystone fabrication equipment used in VHSIC technology	Export Administration Act Per Commodity Control List (EAR)
7.	Design and test generation software	Interim: Arms Export Control Act (ITAR) Final: Upgraded Export Administration Act
8.	Remote design services	Interim: Arms Export Control Act (ITAR) Final: Upgraded Export Administration Act
9.	Basic (university) research results	No control

3. Increase enforcement of existing critical technology transfer and equipment regulations to deny potential adversaries access to already embargoed critical items.

4. Review VHSIC and other DoD VLSI/microelectronics contractor programs, with the advice of the Advisory Group on Electron Devices, to identify and implement appropriate controls as shown in Table 3. Predesignate projects with respect to applicability of controls before contracts are awarded.

5.0 FUTURE TECHNOLOGY EFFORT

Question: What solid state electronic program lies beyond VHSIC? What should be emphasized in current research under the DARPA Program for eventual transition to the VHSIC Program?

Findings: Since the mainstream of electronic advances will be based on silicon devices for the next several decades, a solid state electronics program to follow VHSIC will necessarily be focused on the next generation of those capabilities that are now the focus of VHSIC. Solid state devices based on other materials will continue to be important for a variety of special applications. Increased coordination between the several DoD agencies engaged in VLSI R&D is highly desirable and improved dissemination of technical results from those several programs should be required.

Background: The VHSIC and DARPA programs of DoD have resulted from recognition that, for military systems to have the best of solid state technology, it is necessary for DoD to participate in the development of that technology. Military systems do not constitute a large enough market share to engender responsiveness to their specific needs on the basis of potential sales. The VHSIC Program has provided leverage to bias the large commercial VLSI efforts so as to be more responsive to defense needs. There is no reason to believe that this situation will change. Therefore, a continued presence of DoD in solid state electronics, specifically VLSI, will be required beyond the time span of the VHSIC Program. The $20 M/yr DARPA VLSI program in systems, devices, processes, and materials research is carried out primarily in universities and is not structured for a defined time span. It should continue to support the generic technology base. A continuation of a parallel development effort, like VHSIC, will be required to meet the continuing requirements of military systems for VLSI devices that respond to their unique needs and that maintain a technology lead in that area. Integration of other DoD VLSI activities with VHSIC has not occurred, and results of these other programs are not disseminated to the VHSIC community.

The organizations and people that constitute the U.S. solid state electronics community are constantly searching for new and better devices from which to construct systems. History shows a string of unparalleled

TABLE 3. VHSIC RESEARCH PROGRAM CATEGORIES*

CATEGORY	CONTROL	MOST LIKELY CONTRACTORS
1. Research that will not result in EAR** controllable technology	No restrictions	Universities
2. Research that might result in EAR** controllable technology	No restrictions during research phase. Contractor must agree to review of publications by contracting officer's technical designee.	Universities and other research contractors
3. Research and development that will result in EAR** controllable technology	Temporary ITAR control, final control under EAR.**	Merchant-market semiconductor, manufacturing equipment, and software companies
4. Research and development that will result in single-use defense article technology	National security classification and ITAR control as appropriate.	Defense systems companies

*Category to be determined by contracting officer with the advice of AGED.

**EAR as used here refers to modified EAR technology controls per Recommendation 2.

successes in this search. At any time, there may be a half dozen technologies being advanced and tested for their role in the market. During these last two decades, silicon technology has been so successful that it has already created a $10 billion/year U.S. industry, forecast to reach a $100 billion/year by the year 2000. No other electron device technology is within two orders of magnitude of this market level. The momentum achieved, mostly by integrated circuits, is so great that it locks electronic systems into silicon devices for a long time, and it will take a very distinct advantage in any other technology to even begin to make inroads into the mainstream of electronic systems, however, by the end of the century it is possible that technologies based on other materials may begin to play an increasingly important role in VLSI but will not supplant silicon.

Advances in the silicon device area in the next decade will be focused on applications-oriented attributes of the devices and their fabrication rather than the device technology. Logic architectures, built-in-test, maintenance-free-systems, CAD/CAM/CAT, custom chip design/fabrication, and low costs will be the driving forces that create a systems-on-silicon era in defense electronics. Device technology and processing will continue to advance, particularly when associated with these driving forces. The massive demand for semiconductor memory will be the greatest single driving force. A list of candidate research topics for fueling these advances is given in Table 4. A beyond-VHSIC program should thus be focused on the technology insertion of the submicrometer chips that reach pilot production in Phase II of VHSIC and in further extension of the technology.

There are application areas for solid state electronics where silicon cannot compete. The III-V compound semiconductor materials are essential for certain very high speed logic, microwave, radiation hardened, and electro-optical systems. Gallium arsenide, in particular, has important applications in microwave amplification and generation, and for sensors. Mercury cadmium telluride is an essential technology for certain optical sensor applications. Magnetic materials and components continue to provide essential functions, and there are regions of the power-frequency domain in which electron tubes have not been displaced. Special devices for applications in which silicon cannot meet the requirements will continue to be necessary.

Defense programs should be planned with full recognition that commercial market developments could again bar DoD from access to the technology mainstream, and that without considerable incentives, an industry devoted to volume production and preoccupied with foreign competition may give no attention to special DoD requirements such as radiation hardness and automatic fault detection.

Recommendations

1. **Recognize in forward planning and budgeting that either VHSIC or its equivalent in DoD development of solid state electronic systems will extend beyond the presently planned VHSIC Program termination in 1986.**

TABLE 4. RESEARCH TOPICS FOR VLSI TECHNOLOGY BASE

- Fail soft VLSI architectures for reliability.
- Process modeling capability equivalent to circuit models.
- Truly nonvolatile RAM.
- Resistless processing.
- Zero-defect silicon slices.
- 3-dimensional device structures.
- Multimaterial (e.g., GaAs/Si) chips.
- Low cost, easily coded ROM.
- Self-test/burn-in elimination.
- Restructurable VLSI.
- Submicron features without submicron lithography.
- New submicron phenomena exploitable for device use.
- A "silicon compiler."
- Fast, high resolution plasma processing and E-beam resist.
- User-friendly design automation.
- Computer architectures that permit linear growth in processing power with added CPU's in a manner transparent to the user.
- Multilevel interconnects.
- Integrated sensors.
- Combined MOS/bipolar processing.
- High-speed, high-power packaging technology.
- Testing and test automation.
- Optical signal interfaces.
- Process automation with feedback control loops.
- Architectures and algorithms.

Emphasis should be placed on insertion of VHSIC-II technology and on further extension of VLSI technology.

2. Maintain a balanced solid state electronics program in which silicon devices are accepted as the most important components of military electronic systems for the foreseeable future but in which specialized device technologies based on other materials are recognized as making essential contributions to electronic technology.

6.0 UNIVERSITY PARTICIPATION

Question: What is the proper relationship between the university community and the VHSIC Program? Should the DoD research (6.1) program be directed to support VHSIC technology?

Findings: Universities have and will continue to make important contributions to the DoD VLSI/VHSIC activities by (1) providing important creative and innovative inputs to generic materials, processing, device, and systems science and technology, and (2) by training the personnel that are critical to the continued development of military technology in this field.

DoD university related VLSI research activities include areas of critical importance to VHSIC. The coordination of these activities and the dissemination of research results from them required added emphasis.

Background: The DARPA VLSI program is centered around university participation in the expansion of the generic VLSI technology base and in the training of personnel in this field. The VHSIC program in its Phase III includes six universities which are studying generic technologies of particular interest to the program objectives. In addition, existing and planned 6.1 programs of the Services include important areas of device and system technology that are closely related to VHSIC. Beneficial coordination is being obtained in some of these programs. External to DoD, programs such as the National Research and Resources Facility for Submicron Structures supported by NSF at Cornell, the Center for Integrated Systems at Stanford, and the Microelectronics Center of North Carolina are important resources.

Discussion: One of the reasons for limited university participation in Phase III of VHSIC was that because of the DARPA program and other available funding, the limited university capabilities for VLSI research were saturated.

It appears appropriate to predesignate research programs as generic research and not subject to export controls if they are unlikely to result in EAR controllable technology. Other programs that either might or will result in EAR controllable technology, or that with well-defined military

objectives should be subject to the appropriate controls as outlined in Table 3. By predesignation, there would be no confusion, and participation in a program subject to controls would be with prerecognition and acceptance of the controls. However, each of these programs should be considered as an individual case and an appropriate decision made. AGED is an appropriate group for advising DoD on appropriate controls for proposed projects. Existing university programs in VHSIC could be completed with recognition that their research is generic in nature.

It must be noted that critical recipe technologies are included in design automation, device modeling, and other areas of VLSI/VHSIC research that are performed in university programs. As discussed in Section 4.0, the applicability of controls in these areas requires careful review by a technically competent body.

An appropriate system of review and control must allow mechanisms for support of university research without unacceptable restrictions and, at the same time, development of a protected design and processing technology base in VLSI.

University research programs in materials, devices, phenomena, software, architecture, design, or processing that are generic in nature and not likely to result in direct application to a defense article or in a recipe technology should not, therefore, be subjected to controls. It is important to note that in the university environment many options are investigated while only a few become important to and are adopted by the producers of VLSI. It is only when the applicability is apparent that controls should be considered. Contributions to the general store of knowledge in a field of research does not qualify under these guidelines for application of controls. Thus, a large percentage of academic research may continue without controls, but in those several areas where academic research is leading or very closely coupled to the forefront of defense essential technology, then continued participation may well entail the adoption of appropriate responsibilities with regard to export.

The ambiguities that exist with any system of information control would exist with this structure but are acceptable.

The increased coordination among DoD organizations in research associated with VHSIC and the concentration of much of this research in DARPA is symptomatic of a broader phenomena associated with all electronics-related defense R&D. An increasingly large portion of generic research needs in all areas of science and technology related to electronics is common to the Army, Navy, and Air Force; and, because the costs of research in defense sciences are increasing more rapidly than the available resources, it is becoming necessary to focus the research investment through DoD coordination and assignment of lead agency responsibilities. The VHSIC Program may itself spawn similar programs in maintenance-free electronics, increased weapon system automation, or microprocessor-based personnel training aids. One cannot escape the notion that a more cohesive management of DoD R&D is required in order to meet the continuing challenge of an affordable but unchallengable defense capability.

In connection with 6.1 research activities, universities offer research capabilities in fields that could be, but are not now, involved in VLSI research. Mechanical engineering can provide insights for improved lithography equipment, direct steppers for example. Physics can contribute with improved optical systems or ultrasmall feature definitions. Chemistry departments possess capabilities for improving resists, etches, and other materials. When such research is in direct competition with corporate research laboratories, universities are handicapped by the ever increasing equipment needs. However, if synergism can be established through interdisciplinary activities, an effective and exciting role for the universities is possible.

Because of the increasing DoD needs for generic research, the establishment of a significant number of university fellowships (U.S. citizens only) for the purpose of stimulating research in technical areas of interest to DoD including VLSI and related areas of solid state microelectronics is highly desirable. This idea originated in the DSB Summer Study and should contribute significantly to the long-term security of the Nation. It would provide for more interaction between DoD and the academic community, stimulate the universities to find ways to participate substantially in DoD programs, and increase the pool of manpower needed for these programs.

Because of the broad nature of the research coordination problem and the desirability of keeping 6.1 and some 6.2 VLSI research generic in nature, it appears desirable to coordinate through AGED all research related to VLSI and microelectronics among the services and defense agencies in order to obtain more effective DoD research but to do this in a manner that does not add delays to the initiation of the programs. In addition, the results of these research programs should be effectively disseminated to the VHSIC community.

Recommendations

1. Adopt the recommendation of the DSB Summer Study and implement an expanded DoD university fellowship program to produce more qualified technical personnel.

2. Predesignate DoD VLSI research programs with respect to application of export controls, subject to review at any time by OUSDRE. (See Recommendations on Export Controls.)

3. Follow DoD policy with respect to applicability of controls to university VLSI research.

4. Direct DoD research organizations to coordinate all VLSI/microelectronics research through AGED and to disseminate results to the VHSIC community through summary reports on other effective means, but to avoid introduction of delays in the execution of programs.

7.0 INDUSTRY/DoD RELATIONSHIP

Question: Will VHSIC effectively help DoD maintain a major presence in this dynamic industry with less than 7 percent of the market? What else can be done?

Finding: VHSIC, because it is large enough and its goals complement those of the industry, has been highly successful in reestablishing a DoD presence in the semiconductor industry and in obtaining leverage for its investment. In the future, the nature of this presence will depend on where and how DoD buys VLSI. The dissemination of VHSIC results and the availability of VHSIC chips to all DoD contractors remain a vital concern to non-VHSIC DoD contractors.

Background: The VHSIC Program has been successful in reestablishing a major DoD presence in the semiconductor industry. While the DoD share of the semiconductor industry's shipments has declined, the growth of the entire industry (for 1981, estimates range from $6 to $10 billion) has been strong enough to allow continued growth in the absolute volume of industry sales to the military. The low rate of growth of the military market, relative to other major consumers, caused most producers to direct new product development towards other markets. However, the size and projected growth of the military market for electronic systems (projected to be greater than $25 billion by the late 1980's) is a balancing influence. The segment of this market accounted for by VHSIC will be small; however, major military electronics producers perceive a competitive VHSIC capability as a wedge necessary to penetrate or maintain a significant presence in the systems market.

One result is that VHSIC-I contracts are either semiconductor producers with significant vertical integration into systems, system producers that have established major semiconductor production capabilities, or teams of system producers and semiconductor producers. A second result is that considerable leverage has been obtained through reorientation of existing industry developmental efforts to be compatible with the VHSIC goals.

Discussion: The raw sales of semiconductor devices for defense systems and growth of defense investments are only part of the explanation of the success of the VHSIC Program in attracting the attention of industry. VHSIC has become a significant influence on the industry structure; that is, the environment in which firms make decisions concerning price, output, investment, research and development, and business practices. More specifically, VHSIC has provided military electronics producers with a clear-cut DoD objective and with a well-defined competitive environment. For the VHSIC contractors, an implication of this competitive environment is the need to complement VHSIC dollars with company funds. From a DoD perspective, this acceleration in spending and redirection of funds towards a specified DoD objective is a significant sign of DoD's leverage vis-a-vis the industry.

In formal terms, the scope of VHSIC competition has already narrowed --only six of the nine Phase 0 winners were successful in obtaining Phase I contracts--and may narrow again in the future. This narrowing of competition is apparent but not real. Even before the first VHSIC contracts were opened for bidding, a sizable number of military electronic producers, large and small with a variety of specialties, redirected and accelerated research and development activities towards the announced objectives of the VHSIC Program. As the program has and will progress, firms in the military electronics market which could not win or were unsuccessful in attempts to win VHSIC contracts, are nevertheless forced to carry on VHSIC-like activities at an accelerated pace if they wish to maintain their position in military electronics. There is a limit to this type of leverage; for example, VHSIC funding could be so large that it would outstrip the ability of non-VHSIC contractors to stay in the race. Yet, in the specific situation, it is probably true that this point has not been reached, given the size and resources of significant non-VHSIC contractors like Boeing, RCA, General Electric, and Lockheed, to name a few.

Competition is then successfully being employed in the VHSIC Program to maintain a significant DoD presence in the industry. This statement is equally valid when applied to either the formal program participants or the larger military market.

To stress DoD's apparent success to date in using competition to maximize its leverage vis-a-vis the industry is not synonymous with contending that VHSIC has altered the course of the larger electronic industry. The contrary is the case, and another significant part of the explanation for VHSIC's success. In certain key dimensions, the VHSIC Program has been structured to complement the directions that industry is currently taking. The technical goals of the program, particularly those established for Phase I, are seen by industry to be consistent with their own independent objectives. This point is particularly important where firms producing components for the merchant market (Texas Instruments, National Semiconductor) are concerned. DoD must recognize that departure from the commercial mainstream is very expensive. It was because DoD insisted on making LSI a custom business that DoD never realized the advantages of LSI technology that accrued to the commercial, industrial, and consumer markets. In addition to the consistency of the program and industry's technology goals, the strategy of vertical integration adopted by the program is consistent with the current direction of the industry as evidenced by recent investment and acquisition behavior.

A final point of no small significance in explaining the industry's attention attracted by VHSIC, is the program's prominence as the largest Federal Government technology initiative in microelectronics. This prominence has not always been beneficial in that the program has at times been attacked for failing to achieve goals or to address issues it was not designed to contend with. Nevertheless, the lack of governmental initiatives in other microelectronic technology areas has probably allowed VHSIC to attract more and better industry attention.

Many guidelines for maintaining a significant DoD presence in the semiconductor and broader electronic industry in the future can be drawn from the success VHSIC has enjoyed to date. Certainly, the use of competition to maximize the leverage of DoD's limited resources is a major one. The need for DoD to mainstream or complement the industry's organizational and technological thrust also stands out. In this area, the question of military specifications is likely to be a continuing issue. In addition, the Tri-Service management structure chosen by DoD has probably increased program visibility and industry responsiveness.

It should be noted that to state guidelines and have sufficient knowledge to implement them are two different enterprises. That is, in order to design, implement, and reap the benefits of electronic technology programs in the 1990's, DoD planners will have to make their best guess as to:

- Where the technology trend will lead.
- Will the industry be more or less integrated?
- Will the DoD supplier base shrink or expand?
- Will foreign competitors dominate technology's cutting edge?
- Will other nonmilitary governmental technology initiatives be undertaken?

Certainly, options must be considered as to where DoD VLSI requirements are met: in the merchant semiconductor houses, in commercial silicon foundries, in fabrication facilities operated by system producers, or in a DoD captive operation. It may be, for example, that 70 percent of 1990 DoD VLSI originates in the merchant large-volume producers and commercial foundries, 25 percent in facilities of the military system producers, and 5 percent in a DoD owned facility that specializes in critical, specialized VLSI chips for hardened, cryptographic, or similar applications. At present, Sandia Laboratories maintains a captive facility for producing hardened devices for the nuclear weapons community.

The most important impact of VLSI/VHSIC on industry in general and DoD suppliers in particular will probably arise from the future ability to implement radically more powerful system architectures and processing strategies economically. It is the intent of the DoD to make the major results of the VHSIC Program available on a reasonable basis to those companies that are not participating in a major way in the VHSIC Program.

Concern for the source of DoD VLSI in the future is a real one--but only part of the relationship. We should also be concerned about: (1) source of DoD VLSI for noncontractors of Phases I and II; (2) availability of VLSI design automation tools and systems to all DoD contractors; (3) availability of algorithms and architecture for processing and self-test diagnosis; and (4) process technology (MOS, bipolar, lithograph, E-beam and

X-rays, modeling). Given the increased VLSI efforts by non-VHSIC participants, perhaps the optimum benefit to DoD would arise through a fairly wide sharing of results and tools. This is not easy to arrange, the MITI approach in Japan does not work in the U.S. Mechanisms for sharing the results at some level of detail, and at least for DoD procurements, should be developed.

One of the highest leverage investments that can be made in VHSIC technology is in semiconductor processing equipment. This equipment industry is very fragmented, the companies are generally small, R&D budgets are small, and well-placed DoD funding can make a big difference in the ability of VHSIC systems contractors to meet the needs of DoD and can assist the U.S. semiconductor industry in a highly important way.

Recommendations

1. Continue DoD presence in the semiconductor industry after the completion of the VHSIC Program by means of a VHSIC-like program that addresses the next generation of VLSI devices for military systems in order to assure a source for future DoD VLSI to meet the bulk of DoD VLSI needs with devices from the commercial mainstream.

2. Participate in industry initiatives directed toward meeting manpower and research needs of the U.S. microelectronics industry (such as the proposed Semiconductor Research Cooperative).

3. Provide effective mechanisms that assure dissemination of technical information developed in VHSIC and other DoD VLSI programs to all DoD contractors and for assuring the early and continuous availability of VHSIC chips to non-VHSIC DoD contractors.

8.0 STANDARDIZATION

Question: What standardization measures are recommended to assist the economical utilization of this technology without stifling innovation?

Finding: Standardization should be limited, at this time, to the assurance of interoperability and should not be applied to chip types or technologies. At an appropriate time, interactions with users will determine form, fit, and function.

Background: VHSIC includes planning for standards development relating to chip interfaces, packaging, testing, bus architectures, documentation, and hardware descriptive language in order to assure interoperability.

Discussion: There are a variety of familiar reasons for standardization in defense hardware. Standardization for VLSI is motivated by not only all of the familiar reasons but also others based on the nature of VLSI. Because VLSI chips are complex digital data processors, standard bus architectures and design interfaces will be required to attain interoperability. To facilitate data transfer between companies with proprietary design and manufacturing capabilities, a standard hardware descriptive language is needed. Other standards are required with respect to supply and signal voltages. All of these standards apply to external attributes of the packaged VHSIC chip, not the internal structure or architecture; i.e., the chips and their applications are intended to be implemented in a variety of technologies and with full freedom to incorporate innovations in their designs. To make this approach acceptable, adequate functional descriptions, a high reliability, and provision of built-in-test features are necessary to assure the user that his requirements are being satisfied. The VHSIC approach to standardization is consistent with these factors and is being formulated by the VHSIC Steering Committee on a schedule appropriate to the program.

As VHSIC matures, standardization will become of increasing concern, and mechanisms to address standards should be developed. The standards community must prepare for VHSIC since early insertion is planned and application of inappropriate standards would cause much difficulty.

Recommendations

1. Establish a committee consisting of representatives of government and industry standardization officials to recommend appropriate standards and to consider means for their implementation.

9.0 VHSIC AS A MODEL

Question: Should VHSIC be a model for other vertically integrated technology-based programs?

Finding: The organizational structure of the VHSIC Program is an appropriate model for the vertical integration of other DoD technology-based programs.

Background: The VHSIC Program is structured vertically in order to obtain timely insertion of the technology into the operational inventory and to focus the available funding on well-defined goals. Vertical integration, for VHSIC, means development of the technology, components, and demonstration systems under one management structure and one budget for the three Services. It is implemented by means of a line item budget, an executive committee, a steering committee, and a program office. Each committee

includes representatives of the three services and other agencies, and is chaired by a DoD official. The Program Office is situated within the OUSD Research and Engineering.

Discussion: The VHSIC Program's strategy of vertical integration may be described in terms of its technological thrust, the character of the participating contractors (or contractor teams), and DoD's management objectives. These elements, while separable in form, are strongly interrelated.

The program's goals are ultimately systems oriented, implying that advances in basic device technology are insufficient without accompanying systems development. The description of the program's technological thrust as "top down" is appropriate. The program's technical goal, while decomposable into specific device feature size, speed, fabrication, or software terms, is ultimately the timely integration of dramatically improved electronic capability into working systems. This goal drives the program's supporting technology and requires the vertical integration of each supporting product or process technology development phase. The program's technical thrust is consistent with that of the semiconductor industry.

The vertically integrated technology thrust of the program provides the primary rationale for vertically integrated contractors or contractor teams. Each of the Phase 0 bidders was led by a contractor with established systems capability in order to match the systems level objective. Contractors choosing to bid alone were forced to present strong evidence of their capabilities in each of the successive technology steps necessary to realize the program's goal. Where a systems producer did not possess the entire spectrum of necessary inputs, joint activity or teaming with a contractor possessing the required skill was encouraged. Thus, the vertically integrated characteristic of the VHSIC contractors (contractor teams) mirrors the program's technical goals and requirements.

It is not surprising that the Tri-Service OUSDRE VHSIC Program Office and the individual service program offices also evidence a degree of vertical integration in their management objectives. Successive program phases build upon one another, and a hierarchy of objectives stretching from device speed to actual technology insertion define the management objectives. It could be argued that, to achieve the final program objective of technology insertion into the operational inventory, the degree of vertical integration in DoD management should be extended forward. As a practical matter, the VHSIC Phase I contractor teams will almost certainly move beyond the contracted brassboard demonstrations to developing and proposing VHSIC insertion into weapons systems in development or production. While this step is to be applauded, the past history of difficulty in inserting new technology into systems beyond the prototyping stage would suggest a parallel DoD thrust--a new technology initiative that would be controlled by the VHSIC Program Office is recommended in Section 3.0.

Vertical integration is working in the VHSIC Program because of the program's technical, contractor, and management structure. The emphasis on systems provides a strong case for system based technology building blocks

and the complementary DoD management approach. However, conditions external to the program and its goals have also made significant contributions to VHSIC's success. The independent development of integrated circuit technology and the related structure of the integrated circuit and broader electronics industries are the two most important of these external conditions.

Another element in the success thus far evidenced in the VHSIC Program's strategy of integration is the balancing role of the Phase III program element. Contrary to the vertically integrated technical and organizational character of the Phase 0-II primary program component, Phase III is directed toward specialized contractors (or contractor capabilities) and very specific and discrete technology problems. Thus, the program has availed itself of necessary inputs that might not be provided by any of the integrated contractors or contractor teams. It is recognized, however, that the results of the Phase III efforts will have to be reintegrated with the primary program components; a task to be performed largely by the OSD program management.

Vertical integration in the VHSIC Program is, therefore, evidenced in the program's:

- Technical thrust
- Management objectives
- Contractor base.

The program's dominating system level objectives fit well with an integrated strategy and directly address the "insertion problem," a recognized stumbling block in translating advanced technology into functioning, fielded weapons systems capability.

It is therefore concluded that for technical areas that are of high importance to DoD, the organization of a coordinated thrust such as VHSIC through establishment of a Tri-Service coordination and management function is necessary. Candidates for such thrusts were identified in the DSB Summer Study (Table 5).

Recommendations

1. Extend the VHSIC model for vertically integrated technology base programs to other areas of the technology base. The recommendation of the 1981 DSB Technology Base Summer Study and the specific candidates recommended in that study are supported by this Task Force. These candidates consist of software, machine intelligence, composite materials, high power microwaves, and computer aided training.

10.0 DoD MICROELECTRONICS LABORATORIES

Question: What should be the role of DoD laboratories in the VHSIC/VLSI era?

Finding: It is not practical for DoD to support a proliferation of expensive service laboratories with VHSIC/VLSI capabilities extending to pilot production.

Background: There are, at present, at least ten DoD laboratories and four other government-supported laboratories with varying levels of R&D capabilities in integrated circuits. These laboratories represent a large investment in facilities, estimated at over \$100 M, and exist for a variety of purposes.

Discussion: Present DoD integrated circuit facilities are fragmented and inefficient. Competent personnel for operation of the facilities are difficult to recruit and retain, and the benefits received from the existence of the laboratories are difficult to substantiate. The increased investment required to upgrade these laboratories to provide a VLSI capability is estimated at \$30 to \$50 M per facility; and even if this were done, it is unlikely that competent personnel to operate the facilities could be obtained or even that a sufficient "business" basis exists for providing such multiple capabilities. The present DoD laboratories have not provided an effective interface to industry because they trail the industrial technology in their capabilities.

It is highly desirable that DoD have direct control of facilities capable of fabricating state-of-the-art VHSIC-type devices for special purposes. These facilities should provide a full spectrum of capabilities from design and fabrication to testing and qualification, and should encompass 6.1 to 6.4 and pilot-line programs. Special DoD needs for radiation hardened devices, crytographic processors, and other highly critical low volume applications, or for prototyping and demonstrations would be provided from this facility. These needs are not now being met by the industry nor will they be provided in the future when the required technologies deviate from the commercial mainstream.

The DoD VLSI facilities must be operated by a non-Civil Service staff of from 50 to 200 personnel and be funded at a \$20 M/year rate. There are a number of organizational options for creation of such facilities including captive lines, GOCO's, and FCRC's. Since the cost of these facilities will be significant, duplication for the several services and defense agencies is not reasonable. Furthermore, a given facility should be capable of supplying the special needs of all of DoD. Thus, the facility should be operated by DoD, preferably through a program element assigned to OUSDRE. The justification for more than one such facility should be based

on technology coverage or significant product differences rather than redundancy. Such a difference could be special devices for high security applications.

The objective of a DoD VHSIC Facility should be to serve special needs of DoD entities; plan, generate, and advocate concepts and programs; implement programs inhouse or through contracts and with consultation with users and industry; provide an interface representing the technical areas to other government and industrial entities; and serve as a seed organization for future, broader DoD technology thrusts.

The integration of VLSI facilities with other related DoD technologies into integrated laboratory structures is attractive. DoD is entering an era in which the optimum application of solid state electronics to the information and intelligence aspects of defense systems will be a major discriminator between winners and losers in future conflicts. The recent DSB Summer Study on the Technology Base determined that among the top 17 areas of work that could make an order of magnitude difference, were VHSIC (signal processing), fault tolerance, machine intelligence, and algorithms and advanced software. All of these were rated in the top eight areas. Other studies and opinions uniformly agree that algorithms, architecture and devices need to be together in the same research environment if we are to accomplish "systems-on-silicon."

The way that VHSIC, the Ada Program Office, and the military computer family are progressing as real funded programs could provide the foundation of such new laboratories. The addition of the software technology initiative proposed at $320 M, along with machine intelligence and fault tolerant electronics programs yet to be defined, would round out a funded, long term, highly significant, relevant program; and would define integrated laboratory structures.

Recommendations

1. Do not provide funds for upgrading existing DoD laboratories for VHSIC level device technology. This should not inhibit design and application R&D activities which should be encouraged.

2. Establish an objective of creating one or two DoD-controlled VHSIC/VLSI R&D facilities extending from research to pilot production.

3. Examine in detail the possible combination of the proposed DoD VHSIC facility with the other relevant generic technologies and techniques required to form a DoD Electronics and Information Systems Laboratory.

4. Appoint a special planning committee to identify and evaluate the options for implementing, establish a schedule, and define a charter for this laboratory.

5. Implement the plan.

TABLE 5. TECHNOLOGIES THAT COULD MAKE AN ORDER OF MAGNITUDE DIFFERENCE - THE "BIG 17"

1. Very High-Speed Integrated Circuits
2. Stealth
3. Advanced Software/Algorithm Development
4. Microprocessor-Based Personal Learning Aids
5. Fail-soft/Fault-tolerant Electronics
6. Rapid Solidification Technology
7. Machine Intelligence
8. Supercomputers
9. Advanced Composites
10. High-density Monolithic Focal Plane Arrays
11. Radiation-Hardened Advanced Electronics
12. Space Nuclear Power
13. High-Power Microwave Generators
14. Large Space Structures
15. Optoelectronics
16. Space-based Radar
17. Short-wavelength Lasers

APPENDIX A. TERMS OF REFERENCE

THE UNDER SECRETARY OF DEFENSE

WASHINGTON, D.C. 20301

RESEARCH AND ENGINEERING

3 SEP 1981

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Defense Science Board Task Force on Very High Speed Integrated Circuits (VHSIC) Program

You are directed to undertake an indepth, focussed study to assess aspects of the VHSIC Program outlined below. The implications of this Program are so pervasive and important to the future defense posture of this country that it is imperative that the Program be optimally planned and executed.

The rationale for the VHSIC Program is derived from three points:

a. Potential adversaries have been closing the technology gap in integrated circuits at a significant rate by exploiting our technology advances.

b. Advanced integrated circuit technology (LSI and beyond) has been slow to enter the DoD inventory; consequently, the advantages it offers have not been exploited.

c. Advanced integrated circuit products have principally been designed for commercial application, and, in general, do not meet military requirements for performance, environmental tolerance (including radiation hardening), and low maintenance costs (i.e., on-chip built-in-test and fault tolerance).

The VHSIC Program was conceived and has been implemented to address the points enumerated above in order to make militarized, advanced integrated circuits available, affordable, and easy-to-use for the DoD.

Specifically, this Defense Science Board Task Force should address the following:

a. Is the VHSIC program satisfactorily proceeding with respect to technical, managerial, and political factors in such a way so as to meet the intended goals to develop environmentally and fault-tolerant digital electronics with high signal processing throughput and to introduce this technology into the operational inventory at the earliest possible time? If not, what changes are recommended?

b. Is the funding adequate to meet the goals in the time frame identified in the program plan? If not, how much should it be augmented and how?

c. What policies, directives, incentives and funding should be provided to cause the adoption and use of the VHSIC technology in the next generation of weapon systems?

d. What export controls should be imposed on this technology to prevent the loss of the lead we are gaining on potential adversaries by funding this program?

e. What solid state electronic program lies beyond VHSIC? What should be emphasized in current research under the DARPA program for eventual transition to the VHSIC program?

f. What is the proper relationship between the university community and the VHSIC program? Should the DoD research (6.1) program be directed to support VHSIC technology?

g. Will VHSIC effectively help DoD maintain a major presence in this dynamic industry with less than 7% of the market? What else can be done?

h. What standardization measures are recommended to assist the economical utilization of this technology without stifling innovation?

i. Should VHSIC be a model for other vertically integrated technology-based programs?

This study should consider the Defense Science Board 1981 Summer Study on Technology Base, Chaired by Dr. George Heilmeier; additionally, it should consider the National Academy of Sciences study of the VHSIC program that was recently completed.

This DSB Task Force will be sponsored by Dr. George P. Millburn, Acting Under Secretary of Defense For Research and Engineering (Research and Advanced Technology. Dr. William J. Perry has agreed to serve as Chairman of the Task Force and Mr. Larry W. Sumney, Office of Electronics & Physical Sciences, OUSDRE, will serve as Executive Secretary. Lt. Col. Jerome A. Atkins, USAF, Military Assistant, will be the DSB staff point of contact.

Dick de Lauer

APPENDIX B

MEMBERSHIP

Task Force on Very High Speed Integrated Circuits (VHSIC) Program
"Optimal Planning and Execution of DoD VLSI Activities"

Dr. William J. Perry, Chairman	Hambrecht & Quist
Dr. Robert M. Burger, Vice Chairman	Chief Scientist Research Triangle Institute
Mr. Larry W. Sumney, Executive Secretary	Director, VHSIC Program OUSDRE
Dr. George Heilmeier	Vice President for Corporate Research, Development and Engineering Texas Instruments, Inc.
Dr. Charles M. Herzfeld	Vice President and Director of Research ITT Corporation
Dr. William Howard	Vice President Motorola, Inc.
Professor James Meindl	Stanford University
Dr. Gene Strull	General Manager Advanced Technology Division Westinghouse Defense & Electronic Systems Center
Ivan Sutherland	Consultant, Pittsburgh, PA
Professor Edward Wolf	Director National Research & Resource Facility for Submicron Structures, Cornell University

APPENDIX C

LIST OF INDIVIDUALS PROVIDING INFORMATION TO THE TASK FORCE

D. Adams	DARPA	DARPA VLSI Program
E. Bloch	IBM	Semiconductor Research Cooperative
R. Evans	IBM	Industry Competition
J. Gansler	TASC	Impact of VHSIC
G. Heilmeier*	T.I.	DSB Summer Study
R. Kahn	DARPA	DARPA VLSI Program
D. Kennedy	Stanford University	Export Controls and University Research
C. Meade	Cal Tech	Design Approaches and Intellectual Capital
J. Meindl*	Stanford	Center for Integrated Systems at Stanford
J. Parker	Intel Corp.	Future Technology
R. Reynolds	DARPA	DARPA VLSI Program
J. Shea	Raytheon	VHSIC As Viewed by Other DoD Contractors
G. Strull*	Westinghouse	NMAB Review of VHSIC
L. W. Sumney*	VHSIC Program Director	VHSIC Progress and DoD IC Facilities
D. Toombs	T.I.	Technology Insertion
J. Wade	DoD/PDUSDRE	Export Controls
L. Weisberg	Honeywell	Technology Insertion
R. White	Stanford University	Export Controls and University Research

*Member of Task Force

END

DATE
FILMED

8 82

DTIC